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US 5881828 A **US 5415244 A**
US 5322138 A **US 4108260 A**

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INT CL^7 **E21B**
Other: **WPI, EPODOC, PAJ**

(54) Abstract Title: **Cutter element and drill bit**

(57) A cutter element (10) has a rounded apex (24) offset from the centre line of the cutter element (10) and has a relatively broad and blunt front face (34) and a narrower, more rounded rear face (36). The cutter element (10) may be disposed in the outermost inner row of a rolling cone cutter of a bit with the broader front face (34) facing the borehole side wall so as to resist off centre wear and resultant bit whirl. When placed in inner rows and oriented with the broader and flatter front face (34) being the first portion of the cutting surface to engage the borehole, enhancements in bit durability may be achieved, particularly when drilling through formations of multiple hardness.

Fig. 1

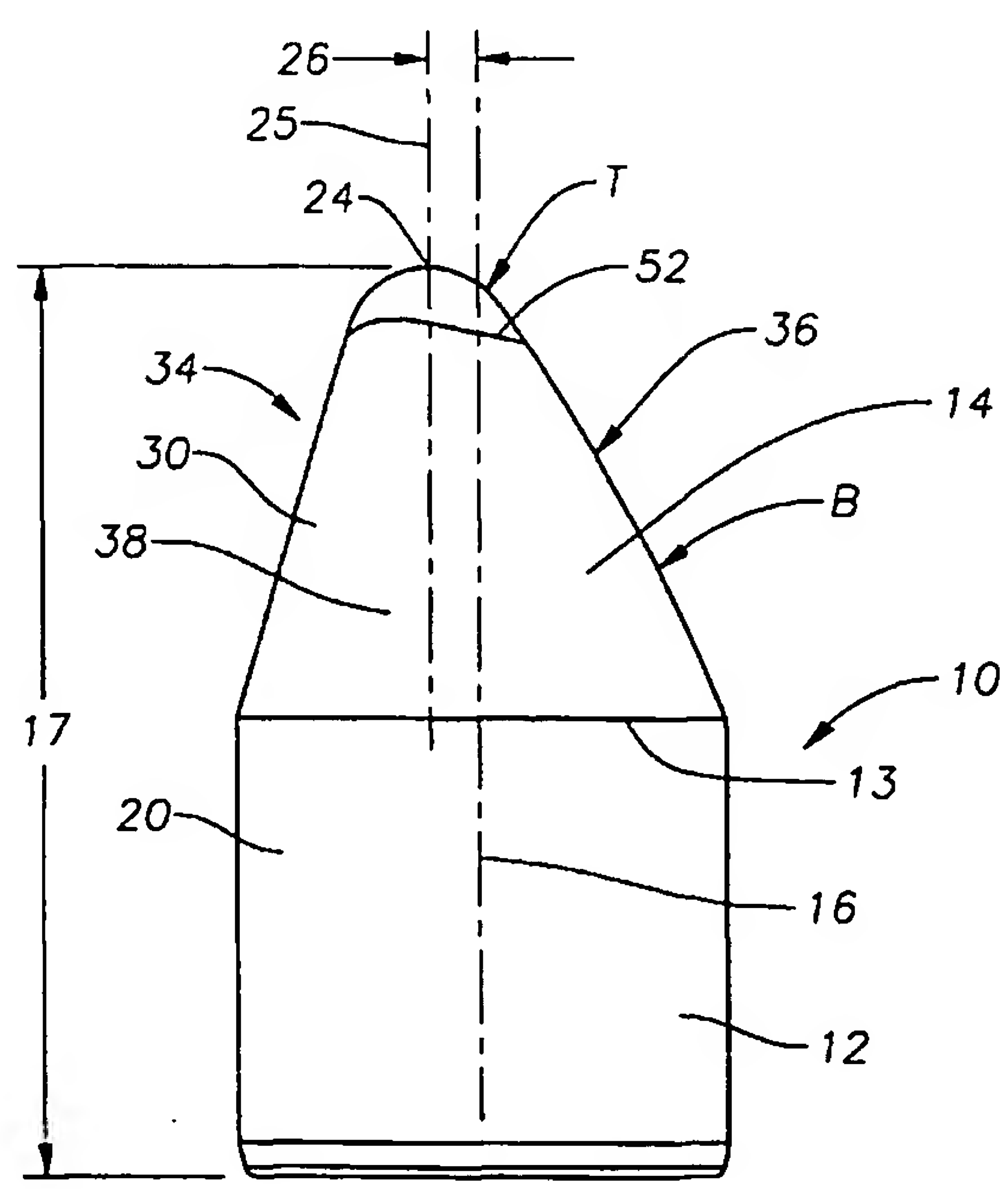

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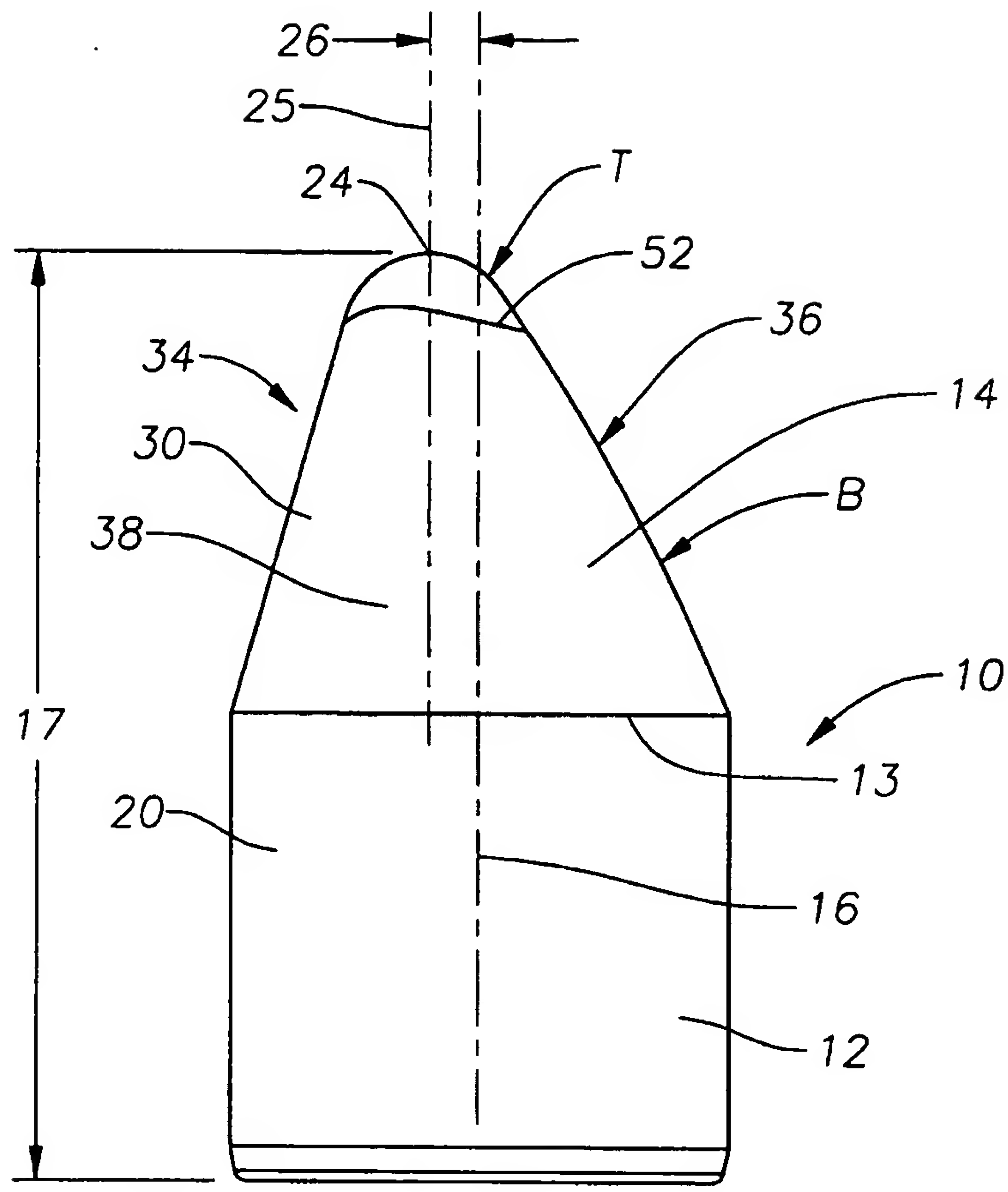
Fig. 1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52
36
14
34
30
B
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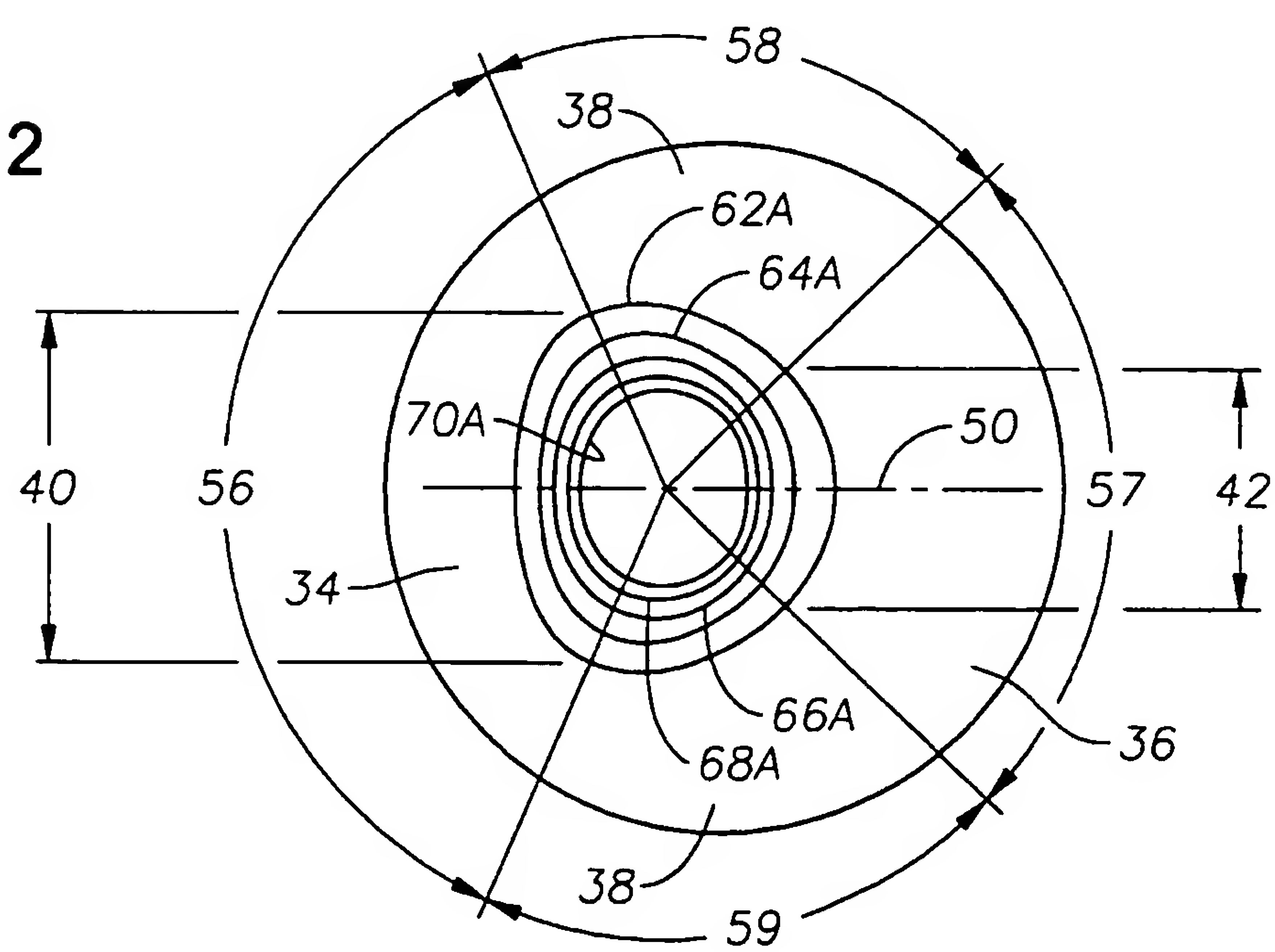
10
13
20
16
12

Fig. 2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70A
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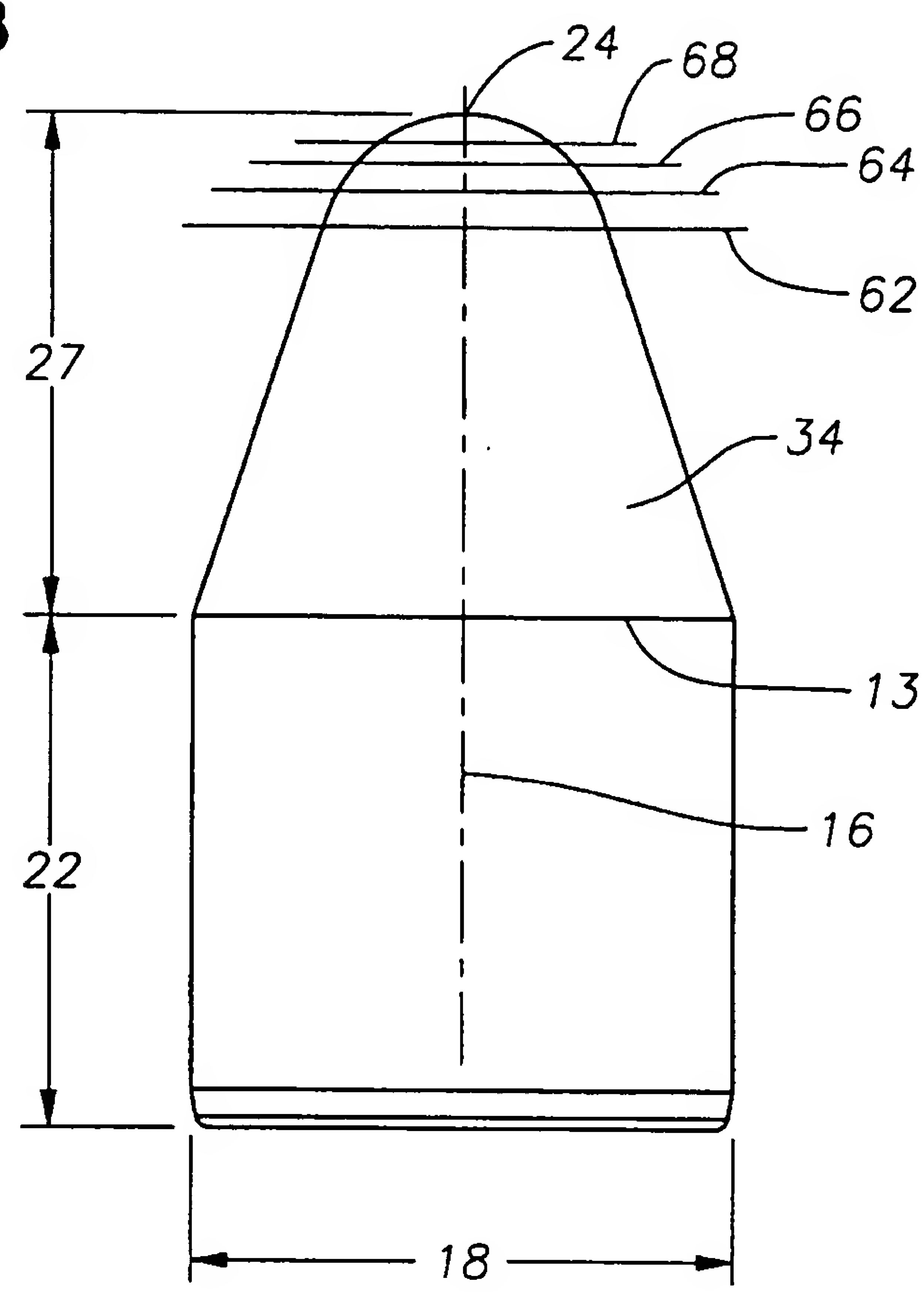
38
59

Fig. 3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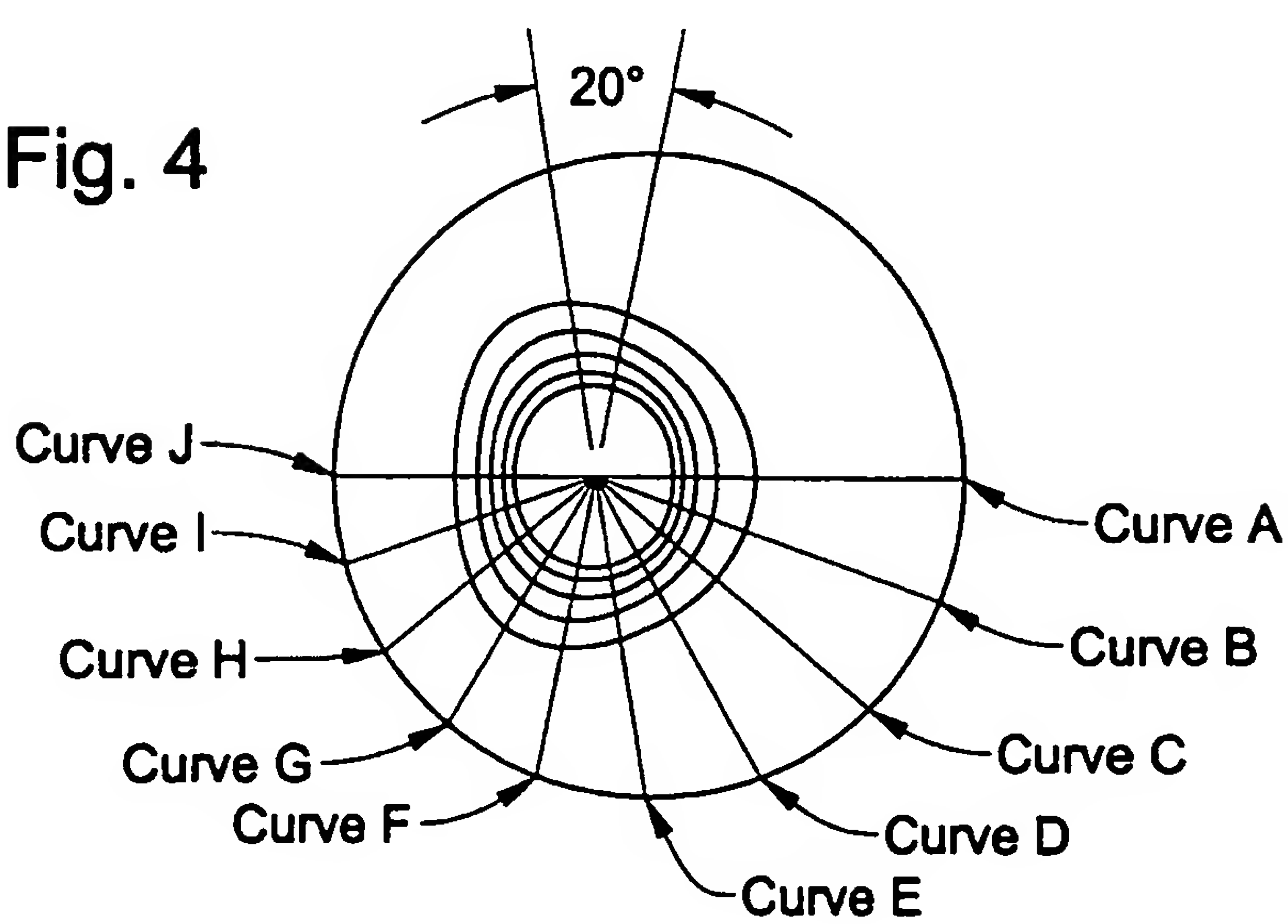
68
66
64
62
27
34
13
16
22
18

Fig. 4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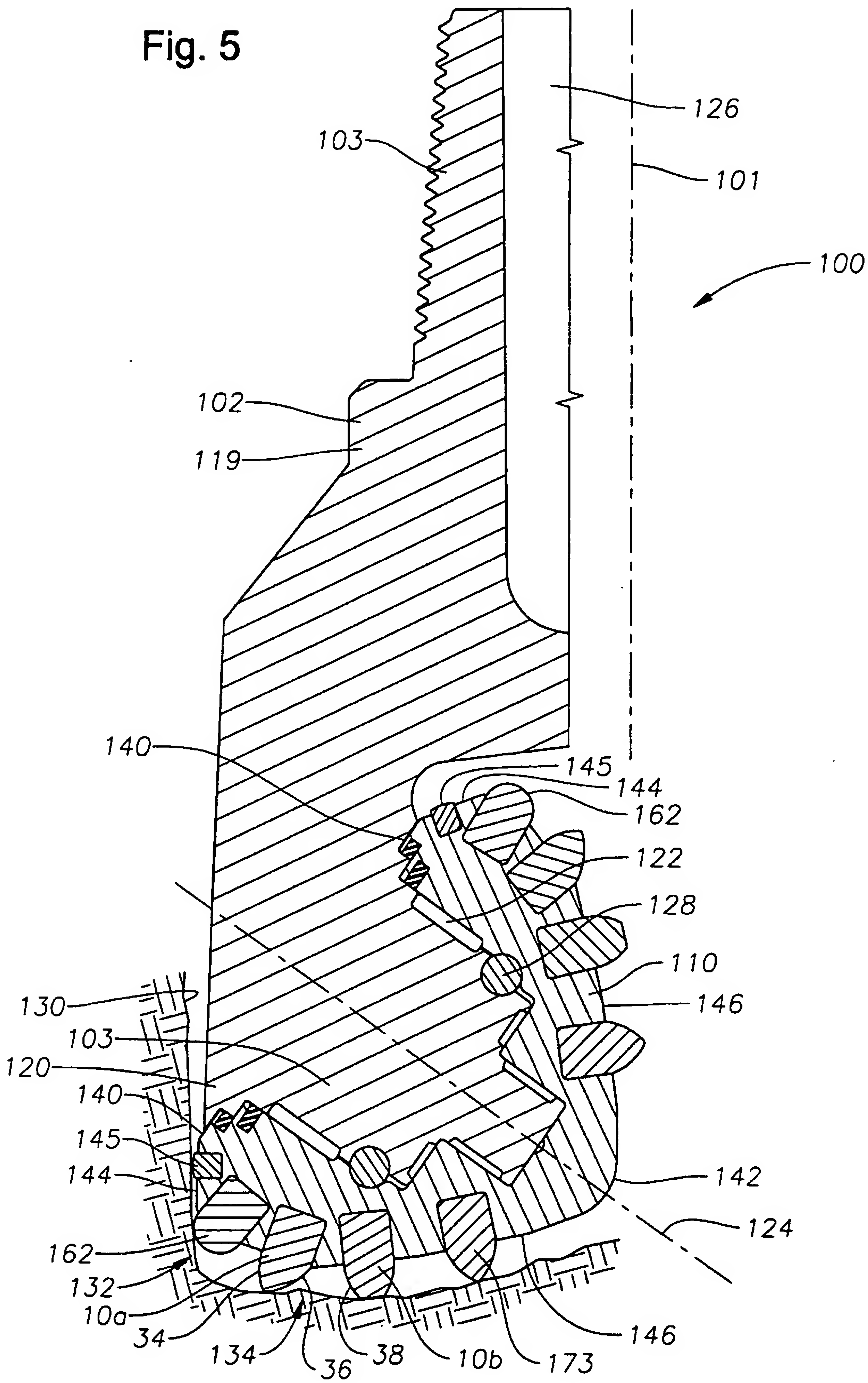
Curve H
Curve G
Curve F
Curve E
Curve D
Curve C
Curve B
Curve A

Fig. 5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102
119
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10b
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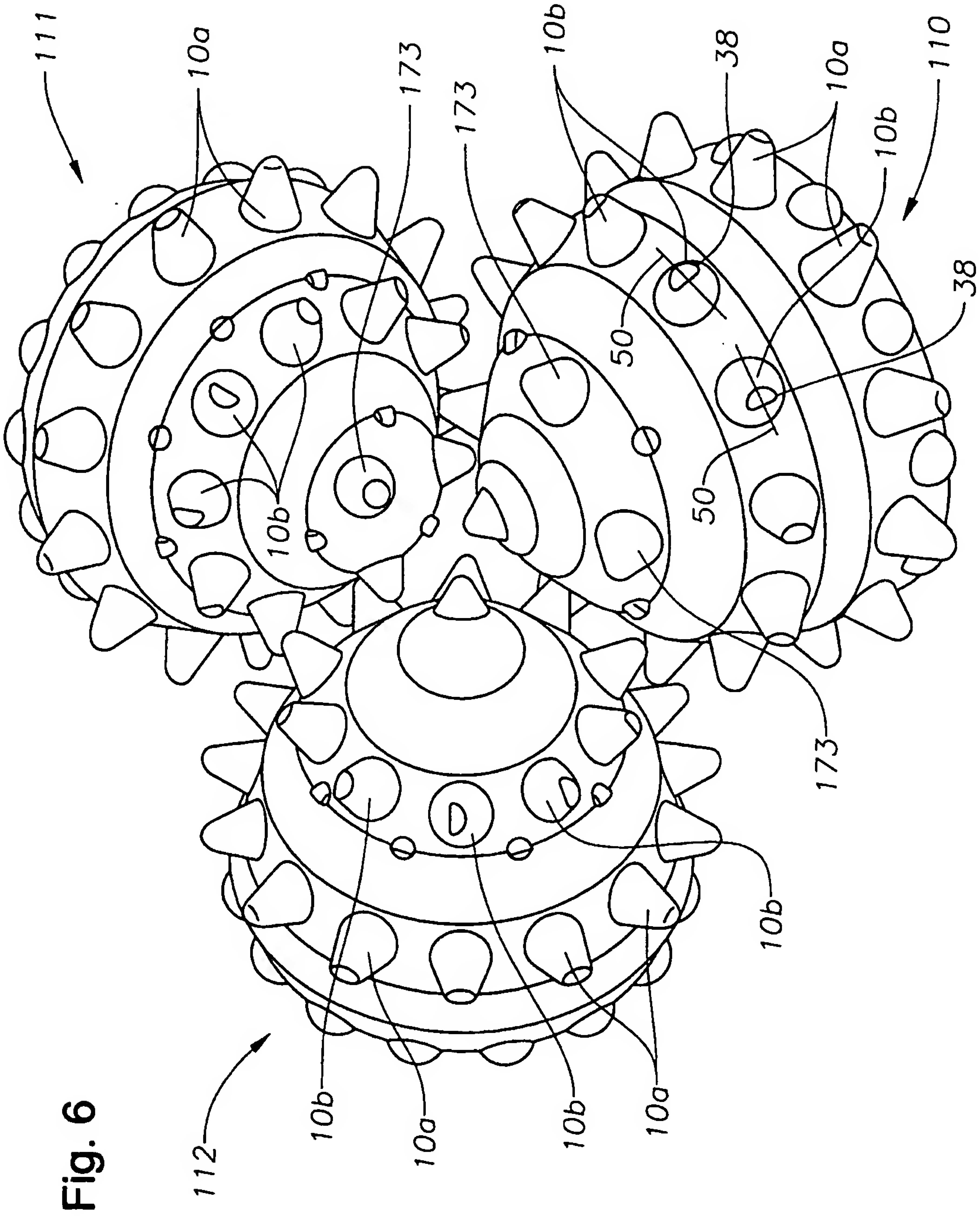
124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10a
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173
10b
38
10a
10b
110
38
50
50
10b
10b
173
10b
112
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10b
10a

Fig. 6

Fig. 7

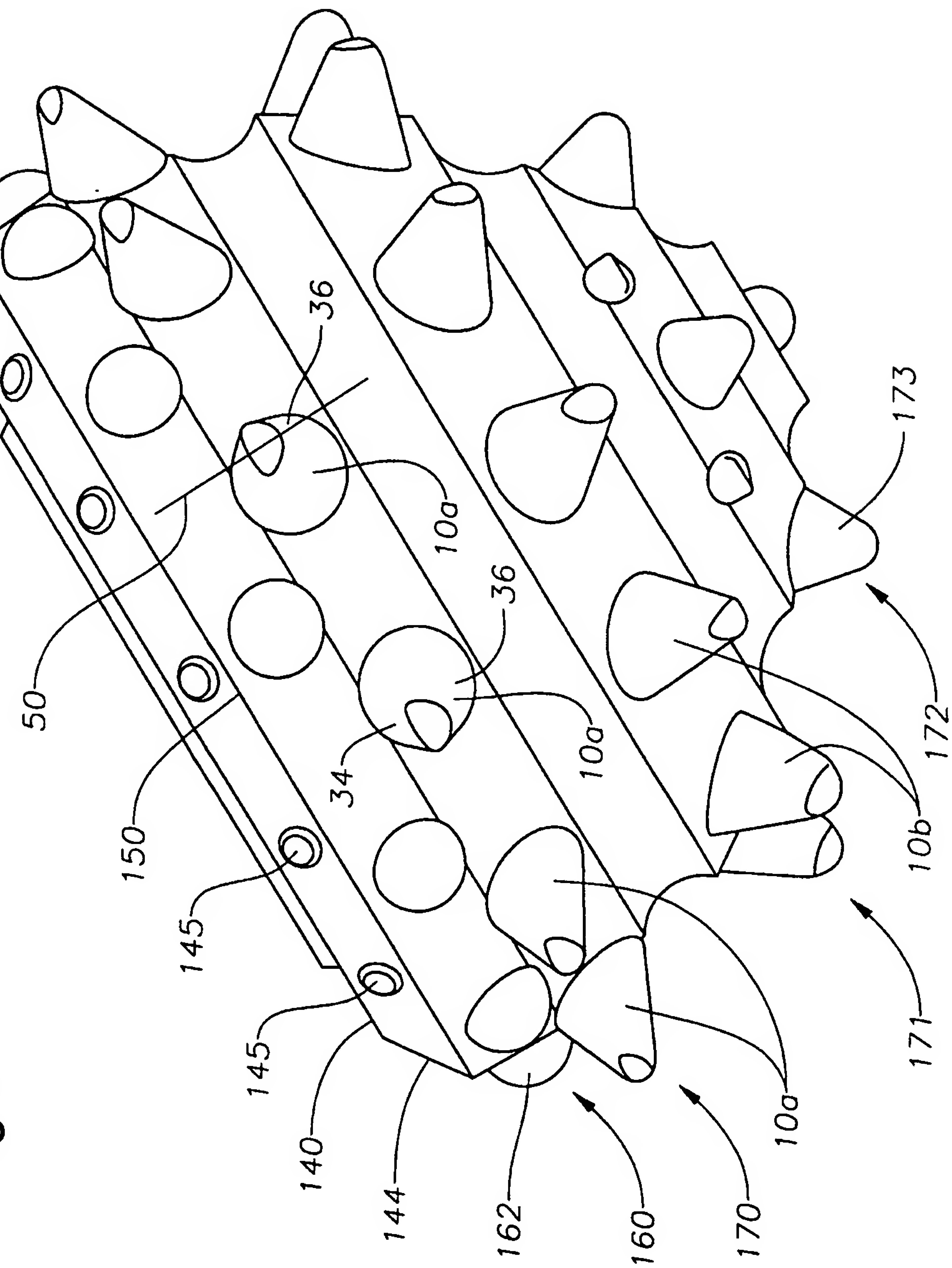

36
50
10a
36
150
34
10a
145
145
140
144
162
160
170
10a
171
10b
172
173

Fig. 8
(Prior Art)

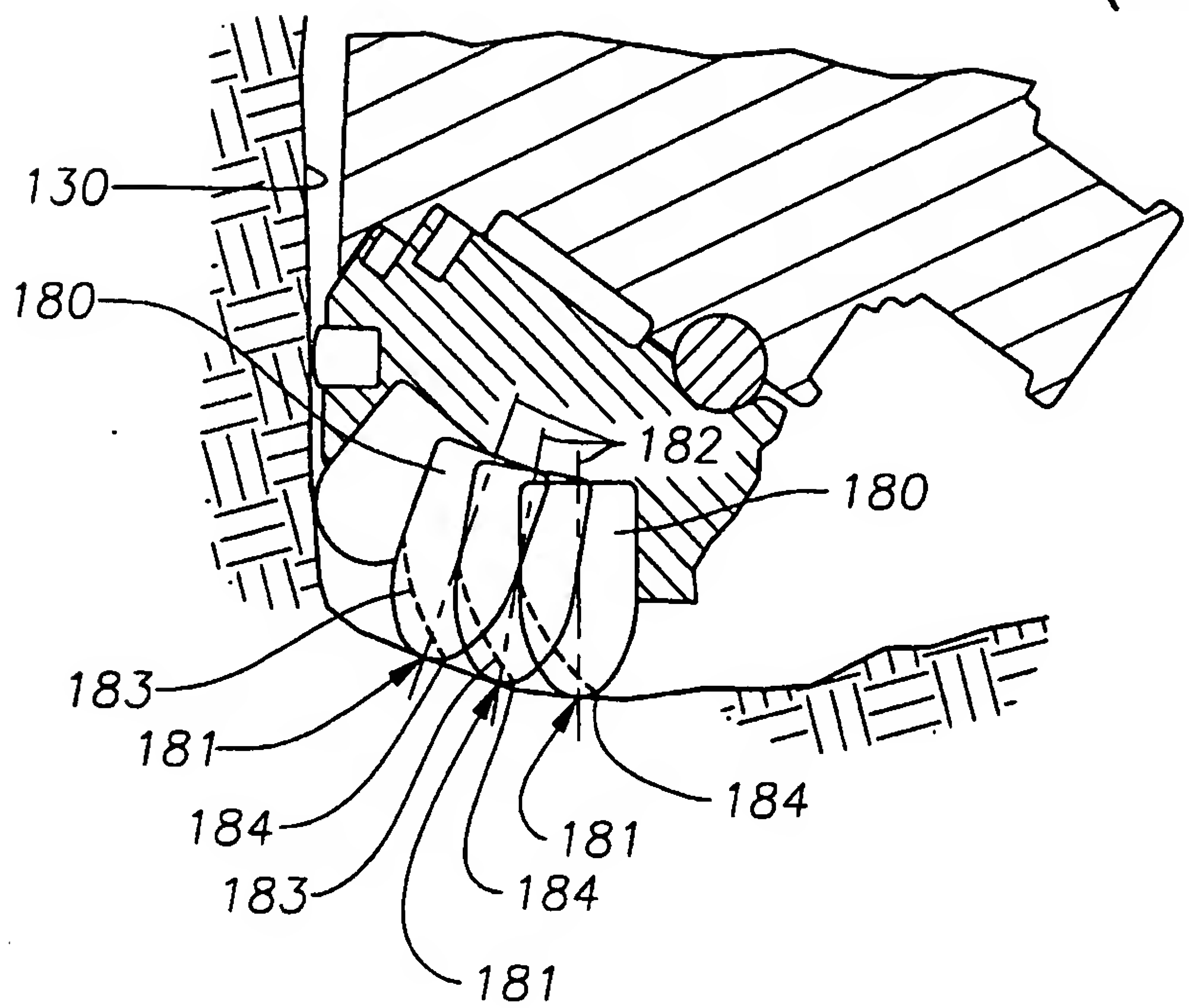
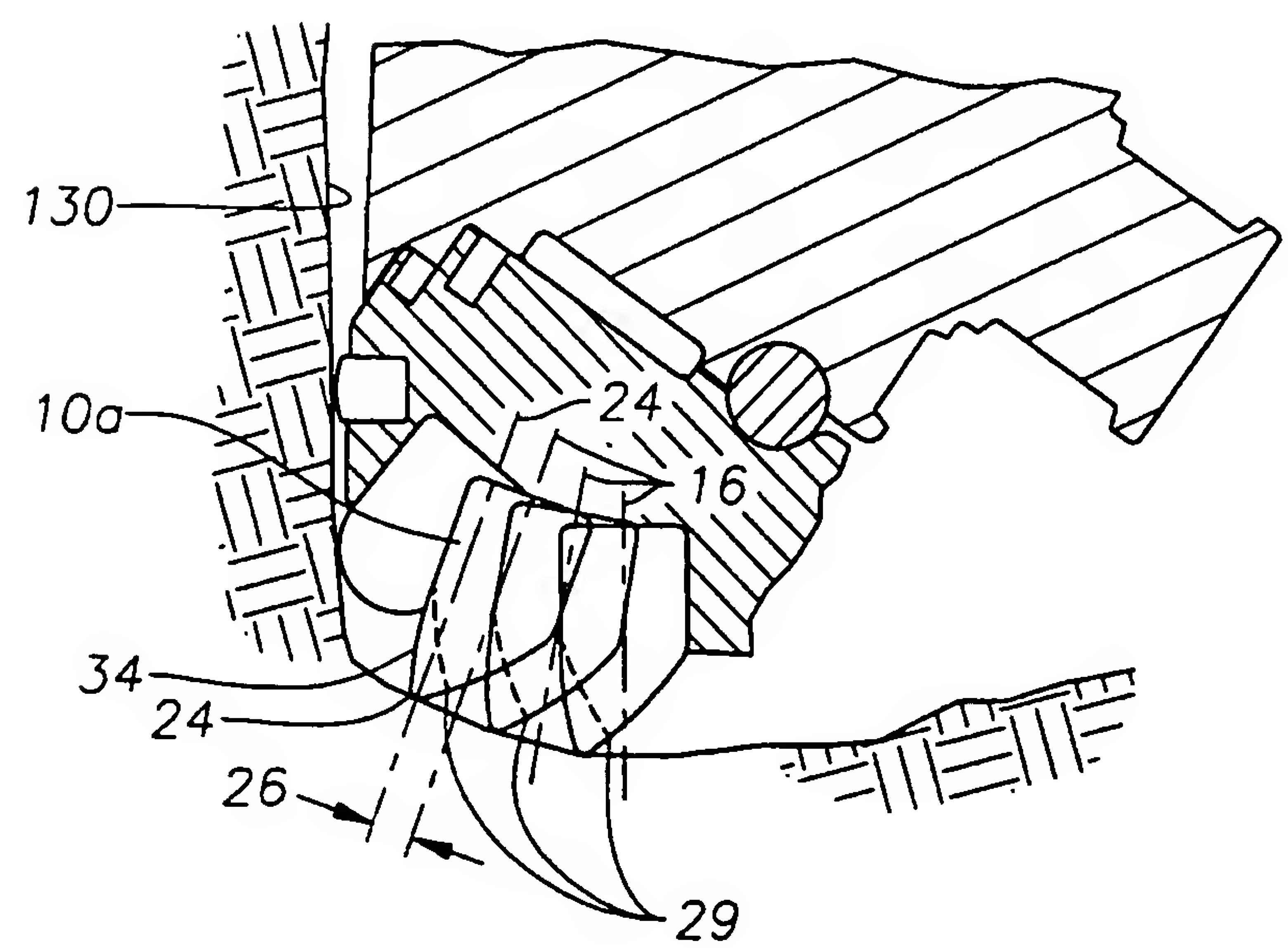


Fig. 9



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CUTTER ELEMENT AND DRILL BIT

The present invention relates to a cutter element and to a drill bit.

The invention relates generally to earth-boring bits used to drill a borehole for the ultimate recovery of oil, gas or minerals. More particularly but not exclusively, the invention relates to rolling cone rock bits and to an improved cutting structure and cutter element for such bits.

An earth-boring drill bit is typically mounted on the lower end of a drill string and is rotated by revolving the drill string at the surface or by actuation of downhole motors or turbines, or by both methods. With weight applied to the drill string, the rotating drill bit engages the earthen formation and proceeds to form a borehole along a predetermined path toward a target zone. The borehole formed in the drilling process will have a diameter generally equal to the diameter or "gage" of the drill bit.

In oil and gas drilling, the cost of drilling a borehole is proportional to the length of time it takes to drill to the desired depth and location. The time required to drill the well, in turn, is greatly affected by the number of times the drill bit must be changed in order to reach the targeted formation. This is the case because each time the bit is changed, the entire string of drill pipes, which may be miles or kilometres long, must be retrieved from the borehole, section by section. Once the drill string has been retrieved and the new bit installed, the bit must be lowered to the bottom of the borehole on the

drill string, which again must be constructed section by section. As is thus obvious, this process, known as a "trip" of the drill string, requires considerable time, effort and expense. Because drilling costs are typically thousands of dollars per hour, it is thus always desirable to employ drill bits which will drill faster and longer and which are usable over a wider range of formation hardness.

The length of time that a drill bit may be employed before it must be changed depends upon its ability to "hold gage" (meaning its ability to maintain a full gage borehole diameter), its rate of penetration ("ROP"), as well as its durability or ability to maintain an acceptable ROP.

A typical rolling cone earth-boring bit includes one or more rotatable cone cutters that perform their cutting function due to the rolling movement of the cone cutters acting against the formation material. The cone cutters roll and slide upon the bottom of the borehole as the bit is rotated, the cone cutters thereby engaging and disintegrating the formation material in its path. The rotatable cone cutters may be described as generally conical in shape and are therefore sometimes referred to as rolling cones.

The borehole is formed as the gouging and scraping or crushing and chipping action of the rotary cones remove chips of formation material which are carried upward and out of the borehole by drilling fluid which is pumped downwardly through the drill pipe and out of the bit. The earth disintegrating action of the rolling cone cutters is enhanced by providing the cone cutters with a plurality of cutter elements. Cutter elements are generally of two

types: inserts formed of a very hard material, such as tungsten carbide, that are press fit into undersized apertures in the cone surface; or teeth that are milled, cast or otherwise integrally formed from the material of the rolling cone. Bits having tungsten carbide inserts are typically referred to as "TCI" bits, while those having teeth formed from the cone material are commonly known as "steel tooth bits." In each instance, the cutter elements on the rotating cone cutters break up the formation to form new borehole by a combination of gouging and scraping or chipping and crushing.

The shape and positioning of the cutter elements (both steel teeth and tungsten carbide inserts) upon the cone cutters greatly affect bit durability and ROP and thus are critical to the success of a particular bit design.

The inserts in TCI bits are typically positioned in circumferential rows on the rolling cone cutters. Most such bits include a row of inserts in the heel surface of the rolling cone cutters. The heel surface is a generally frustoconical surface and is configured and positioned so as to align generally with and ream the sidewall of the borehole as the bit rotates.

Conventional bits typically include a circumferential gage row of cutter elements mounted adjacent to the heel surface but oriented and sized in such a manner so as to cut the corner of the borehole. Conventional bits also include a number of additional rows of cutter elements that are located in circumferential rows disposed radially inward or in board from the gage row. These cutter elements are sized and configured for cutting the bottom of the

borehole, and are typically described as inner row cutter elements.

For the most part, inner row inserts in TCI bits have generally been one of two general shapes. One insert typically employed in an inner row may generally be described as a "conical" insert, one having a cutting surface that tapers from a cylindrical base to a generally rounded apex. Such an insert is shown, for example, in Figure 4A-C in US-B-6241034. Another common shape for an insert for use in inner rows is what generally may be described as a "chisel" shaped. Rather then having the rounded apex of the conical insert, a chisel insert generally includes two generally flattened sides or flanks that converge and terminate in an elongate crest at the terminal end of the insert. The chisel element may have rather sharp transitions where the flanks intersect the more rounded portions of the cutting surface, as shown, for example, in Figures 1-4 in US-A-5172779. In other designs, the chisel insert may be contoured so as to eliminate sharp transitions and to present a more rounded cutting surface as shown for example in Figure 3A-D in US-B-6241034. For various applications, the apex in the conventional conical insert and the crest of the conventional chisel insert may be offset from the central axis of the cutter element as shown, for example, in US-A-4334586.

In general, it has been understood that, as compared to a conical inset, the chisel shaped insert provides a more aggressive cutting structure that removes formation material at a faster rate for as long as the cutting structure remains intact. For this reason, in soft

formations, chisel shaped inserts are frequently preferred for bottom hole cutting.

Despite this known advantages of chisel shaped inserts, however, such cutters have shortcomings when it comes to drilling in harder formations. In particular, in hard formations, the relatively sharp cutting edges and corners of the chisel endure high stresses that may lead to chipping and ultimately breakage of the insert. By contrast, conical inserts, having a more rounded and less aggressive shaped cutting surface, withstand harder formations much better than do chisel inserts. Unfortunately, conical inserts suffer from the shortcoming that they are slower to remove formation when drilling in soft formations as compared to a chisel insert. Accordingly, because of these differences, compromises in the cutting structure of a bit typically must be made based on the type of formation expected. Such compromises may be of little significance in the instances where the formations to be encountered are well known. For example, where the interval to be drilled is known to be composed of only soft formation, it is unimportant that a chisel insert could not withstand a harder formation.

Unfortunately, in many locations, the formation hardness cannot be predicted with such certainty. For example, it is common in certain locations to encounter layers of extremely hard rock interspersed within a long interval of relatively soft formation. In these instances, the driller is faced with a difficult problem. Because of their greater speed when drilling in soft formations, it is desirable to use a cutting structure having a chisel shaped inserts; however, when a layer of hard formation is

encountered, often at unpredictable depths, the chisel shaped inserts will quickly be ruined such that the bit's ROP will drop dramatically, as for example, from 80 feet (approx. 25m) per hour to less than 10 feet (approx. 3m) per hour. Once the cutting structure is damaged and the rate of penetration reduced to an unacceptable rate, the drill string must be removed in order to replace the drill bit. As mentioned, this "trip" of the drill string is extremely time consuming and expensive to the driller.

On the other hand, if the driller were to employ a bit having a cutting structure of conical shaped inserts, a cutting structure that will better survive drilling through the layers of hard formation, the bit's rate of penetration while drilling the soft formation may be intolerably low.

As will be understood then, there remains a need in the art for a cutter element and cutting structure that will provide a high rate of penetration when drilling in soft formation, yet be durable enough to withstand encounters with stringers of hard formation, and that will provide an acceptable ROP through both the hard and soft formation.

Another known phenomenon detrimental to drill bit life and rate of penetration is a wear phenomenon that tends to wear and flatten the cutter element on the side generally facing the borehole wall. As this wear occurs, greater side wall forces are imparted on the bit which tends to lead to bit instability and bit wobble which, in turn, tend to cause the bit to deviate from the intended drilling path and to place greater demands and stresses on the bearings. Furthermore, as the surface of the inserts facing the

borehole wall tends to wear toward the centre of the insert, the insert becomes sharper and more likely to chip and ultimately to break.

Thus, it would also be desirable to provide a cutter element shaped to resist such off-centre wear and, when such wear nevertheless does occur, to resist the tendency for the cutter element to break.

According to a first aspect of the present invention, there is provided a cutter element for a drill bit, the cutter element comprising: a base having a central axis; a cutting portion extending from said base and having a continuously contoured cutting surface terminating in a generally rounded apex, said cutting surface including: a first face extending from said base to said apex; a second face opposite said first face extending from said base to said apex; and, respective transition surfaces extending between said first and second faces and between said base and said apex; wherein said cutting portion is symmetrical about a plane containing said central axis and bisecting said first and second faces; and, wherein said apex is offset a distance from said central axis in the direction of said first face; said first face being flatter than said second face.

According to a second aspect of the present invention, there is provided a cutter element for a drill bit, the cutter element comprising: a base having a central axis; a cutting surface extending from said base and including a rounded apex offset in a first direction from said central axis, said apex being symmetrical about an apex axis that

is substantially parallel to said central axis; a forward facing cutting surface on one side of said apex axis; a rear facing cutting surface on the opposite side of said apex axis from said forward facing cutting surface; wherein said forward facing cutting surface is flatter than said rear facing cutting surface and has a wider cutting profile than said rear facing cutting surface.

According to a third aspect of the present invention, there is provided a drill bit for drilling a borehole in earthen formations, the bit having a nominal gage diameter and comprising: a bit body having a bit axis; at least one rolling cone cutter rotatably mounted on said bit body and having a plurality of cutter elements disposed in spaced-apart circumferential rows; a gage row of cutter elements having cutting portions extending to full gage diameter for cutting the corner of a said borehole; a first inner row of cutter elements disposed radially inboard of said gage row for cutting a said borehole bottom, said first inner row cutter elements having a base retained in said cone cutter, a central axis, and a cutting portion extending from said base; wherein a plurality of said first inner row cutter elements have a cutting surface comprising: a generally rounded apex; a first face extending from said base to said apex; and, a second face opposite said first face extending from said base to said apex; wherein said first face is flatter than said second face and wherein said apex is offset a distance from said central axis in the direction of said first face; and wherein said plurality of first inner row cutter elements are oriented in said cone so that said first face generally faces a said borehole side wall when said cutter element is at its radially outermost position with respect to the bit axis.

According to a fourth aspect of the present invention, there is provided a drill bit for drilling a borehole in earthen formations, the bit having a predetermined gage diameter and comprising: a body with a bit axis; at least one rolling cone cutter rotatably mounted on said bit body and adapted to rotate in a predetermined cutting direction; a gage row of cutter elements on said cone cutter having cutting portions extending to full gage diameter for cutting the corner of a said borehole; a first inner row of cutter elements radially in board of said gage row, said first inner row cutter elements having a central axis and a cutting portion extending from the cone cutter, said cutting portion including a generally rounded apex, a first face extending from the cone cutter to said apex, and a second face opposite said first face and extending from said cone cutter to said apex, said first face being flatter than said second face and said apex being offset a predetermined distance from said central axis in a direction of said first face, said first inner row cutter elements being oriented in said cones such that said first face generally faces a said borehole sidewall when said cutter element is at its radially-outermost position with respect to the bit axis.

According to a fifth aspect of the present invention, there is provided a drill bit for drilling a borehole in earthen formations, said bit having a nominal gage diameter and comprising: a bit body having a bit axis; at least one rolling cone cutter rotatably mounted on said bit body and having a plurality of cutter elements disposed in spaced-apart circumferential rows; a gage row of cutter elements having cutting portions extending to full gage diameter for

cutting the corner of a borehole; a plurality of first inner row of cutter elements disposed radially inboard of said gage row for cutting a said borehole bottom, said plurality of first inner row cutter elements having a base retained in said cone cutter, a central axis, and a cutting portion having a cutting surface extending from said base and terminating in a generally rounded apex, said cutting surface including: a first face extending from said base to said apex; and, a second face opposite said first face extending from said base to said apex; wherein said cutting portion is symmetrical about a plane containing said central axis and bisecting said first and second faces; and, wherein said apex is offset a distance from said central axis in the direction of said first face, said first face being flatter than said second face; and, wherein said plurality of first inner row cutter elements are oriented in said cone so that said first face generally faces a said borehole side wall when said cutter element is at its radially outermost position with respect to the bit axis.

Accordingly, in the preferred embodiment, there is provided herein a generally blunt faced cutter element for use in a rolling cone drill bit. The cutter preferably includes a continuously contoured cutting surface terminating in a generally rounded apex that is offset from the cutter element central axis. The cutter includes a first face that is flatter or more blunt than the second face on the opposite side of the cutting surface. Preferably, the cutter is symmetrical about a plane that passes through the central axis of the cutter and that bisects the first and second cutting face. In this preferred embodiment, the first face includes a wider

cutting profile than the second face, and the cutting surface includes a convex or bowed surface in every longitudinal profile. The wider first face provides a substantial cutting profile, similar to that of a similarly sized chisel shaped cutter; however, due to the continuous contoured cutting surface, the regions of high stress, a potential cause of breakage, are reduced or eliminated.

It is preferred that the cutters be disposed in circumferential rows in the cone cutters of a drill bit. In a first arrangement, the generally flatter and wider first face is disposed in the outermost inner row of the cone cutter, and is oriented such that the first face faces the borehole wall when the cutter is in a position furthest from the bit axis. In this manner, the outermost row of inner row cutter elements provide a relatively broad face to resist off centre wear, and to reduce the resultant bit whirl that may be fostered or caused by off centre wear occurring to the cutter elements in these locations.

The cutter may also be employed in other rows in the cone cutter. For example, depending upon the drilling application, the cutter may be positioned in one or more inner rows and oriented such that its broader and flatter first surface is the first portion of the cutting surface that engages the borehole bottom. In this orientation, the cutter may provide an improved cutting structure to the drill bit enabling it to drill through soft formations with high ROP. In addition, the shape of the cutting surface provides enhanced resistance to insert breakage when stringers of hard formations are encountered by the bit. Thus, this embodiment provides both for high ROP when

drilling in soft formation and enhanced durability to withstand encounters with hard formation.

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a side elevation view of an example of a cutter element made in accordance with the present teachings;

Figure 2 is a top view of the cutter element shown in Figure 1;

Figure 3 is a front elevation view of the cutter element shown in Figure 1;

Figure 4 is another top view of the cutter element of Figure 1 showing various curves on the cutter element surface that correlate with data in Table I;

Figure 5 is a schematic partial section view taken through one leg and one rolling cone of an example of a rolling cone drill bit incorporating the cutter element of Figures 1-4;

Figure 6 is a perspective view of the rolling cone bit of Figure 5 as viewed from the bottom of the borehole;

Figure 7 is a perspective view of one of the cone cutters shown in Figure 6;

Figure 8 is a schematic view, partly in cross section, of a portion of a conventional roller cone bit having conical shaped inserts in its outermost inner rows shown rotated into a single profile; and,

Figure 9 is a schematic view, partly in cross section, of a portion of the cone cutter shown in Figure 7 with the cutter elements shown rotated into a single profile.

Referring to Figures 1-3, cutter element 10 includes a generally cylindrical base portion 12 and a cutting portion 14 extending from base 12. Cutter element 10 generally has an overall length 17. Base portion 12 includes a central axis 16, a generally cylindrical side surface 20 having diameter 18 and length 22. Base 12 joins cutting portion 14 at intersection 13.

Cutting portion 14 includes a continuously contoured cutting surface 30 extending from intersection 13 a distance 27 and terminating in a generally rounded or spherical apex 24. As used herein, the term "continuously contoured" refers to surfaces that can be described as having continuously curved surfaces that are free of relatively small radii (typically less than 0.08 inches (approx. 2mm)) that are conventionally used to break sharp edges or round off transitions between adjacent distinct surfaces. Apex 24 includes apex axis 25 that is parallel to but offset from base axis 16 by an offset distance 26. The dimension of offset 26 may be expressed as a percentage of the diameter 18 of insert base 12. It is preferred that the offset be within the range of 5% to 25% of the diameter 18, and, more particularly, between approximately 7% and 10% of the insert base diameter 18.

As best shown in Figure 2, contoured cutting surface 30 may generally be described as including forward facing or front face 34, a back face 36 opposite front face 34, and a pair of transition surfaces 38 extending between the front and back faces. The cutting surface 30 preferably is symmetrical about a plane 50 that passes through base axis 16 and apex axis 25 and that generally bisects front face 34 and rear face 36. Front face 34 and back face 36 are generally coextensive with that portion of cutting surface 30 defined by angles 56 and angle 57 respectively. Transition surfaces 38 are generally coextensive with that portion of cutting surface 30 defined by angle 58 and angle 59 respectively. Preferably, angle 56 of front face 34 encompasses approximately 120 degrees of cutting surface 30, and angle 57 of rear face 36 encompasses approximately 80 degrees. Angles 58, 59 of transition surfaces 38 each extend about approximately 80 degrees of the cutting surface 30 in this preferred embodiment.

As best shown in Figure 1, cutting surface 30 preferably includes a slight bow or convex shape in every longitudinal profile view and in every cross sectional view where the section is taken longitudinally through apex axis 25. This convex shape is achieved by employing a top radius T and blending it with a bow radius B in order to smoothly contour the cutting surface shape from apex 24 to intersection 13. Curve 52 in Figure 1 generally represents the location along cutting surface 30 at which the top radius T and bow radius B are blended together to form the preferred continuously contoured cutting profile that is free from abrupt changes in radius. The contours and radii describing preferred cutting surface 30 may best be

described with reference to Figure 4 and Table I below, though other top radii T and bow radii B may be employed.

CURVE	TOP RADIUS	BOW RADIUS
A	T	B
B	1.04T	1.06B
C	1.15T	1.14B
D	1.32T	1.23B
E	1.55T	1.35B
F	1.86T	1.48B
G	1.96T	1.69B
H	1.69T	1.58B
I	1.43T	1.61B
J	1.34T	1.45B

As shown in Figure 4, curves A through J designate profiles of the cutting surface taken every 20 degrees along cutting surface 30 from curve A to curve J. As shown in Table I above, both the top radius T and bow radius B are their smallest at curve A. Top radius T increases through curve G where T has its greatest radius. Top radius T decreases from curve G through curve J. Bow radius B increases from curve A through curve G where it is at its maximum. Bow radius B decreases from curve G to curve H, but then increases from curve H through curve I, and then decreases again from curve I to curve J.

Cutter element 10 defined by such continuous curves presents a continuously contoured cutting surface 30 having a relatively flat or blunt front cutting face 34 and a more rounded rear cutting face 36. In this preferred configuration, front face 34 may be said to be flatter or

more blunt relative to rear cutting face 36. As used herein, where a first portion of a cutting surface is described as flatter or more blunt than another portion of the cutting surface, what is meant is that in the closed figure formed by the intersection of the cutting surface and a plane that is perpendicular to the central axis 16 of the cutter element, the radius of curvature of the first portion of the closed figure is greater than the radius of curvature of the second portion.

Referring again to Figure 3, planes 62, 64, 66, 68, which are perpendicular to apex axis 25 and insert axis 16 and that pass through the cutting surface 30, will generally form the cross-sectional closed figures 62A, 64A, 66A and 68A, respectively, as shown in Figure 2. A cross section taken above plane 68 (Figure 3) through the generally spherical apex 25 will be substantially circular, as represented by closed Figure 70A in Figure 2. These cross sectional areas or closed figures likewise illustrate the generally flattened or blunt front-facing surface 34 as compared to the more rounded rear facing surface 36. Also shown in Figure 2, front facing surface 34 includes a cutting profile width 40 that is greater than the cutting profile width 42 of rear face 36. In this manner, when insert 10 is positioned in a rolling cone cutter such that front face 34 is the first portion of the cutting surface 30 to engage the formation, rounded back face 36 may be said to be hidden or protected by virtue of it being narrower and falling within the cutting profile width 40 of front face 34 (when the cutting profiles are viewed as rotated into a single plane).

Cutter element 10 may be employed advantageously in various locations in the rolling cone cutters of a drill bit. The location and orientation of cutter element 10 may be varied as is necessary or desirable to achieve a particular result.

Referring now to Figure 5, an earth-boring bit 100 is shown to include a bit central axis 101 and a bit body 102 having a threaded pin 103 on its upper end for securing the bit to the drill string (not shown). Bit 100 has a cutting diameter as defined by three rolling cone cutters 110, 111, 112 (only cone cutter 110 being shown in Figure 5). Each cutter 110, 111, 112 is rotatably mounted on a bearing shaft 103 that depends from the bit body 102. Bit body 102 is composed of three sections or legs 119 (one shown in Figure 5) that are welded together to form bit body 102. Bit 100 further includes a plurality of nozzles that are provided for directing drilling fluid toward the bottom of the borehole and around cone cutters 110, 111, 112, and includes lubricant reservoirs that supply lubricant to the bearings of each of the cone cutters, such structures being omitted from the figures for clarity. Bit legs 119 include a shirttail portion 120 that serves to protect the cone bearings and seals from damage caused by cuttings and debris entering between the leg 119 and its respective cone cutter.

Each cutter 110, 111, 112 is rotatably mounted on a respective pin or journal 122, with an axis of rotation 124 oriented generally downwardly and inwardly toward the centre of the borehole. Drilling fluid is pumped from the surface through fluid passage 126 where it is circulated through internal passageways (not shown) to the nozzles and

out of the bit. Each cone cutter 110, 111, 112 is secured on pin 122 by locking balls 128. The borehole created by bit 100 includes sidewall 130, corner portion 132 and bottom 134.

Cone cutters 110-112 are substantially similar such that a description of one such cone cutter 110 will be adequate to describe the structure and operation of cone cutters 111, 112 as well. Principally, cone cutters 111, 112 differ from cone cutter 110 (and from each other) in the number and placement of cutter elements, as described in more detail below.

Referring still to Figure 5 and to Figure 7, cone cutter 110 includes a backface 140 and nose portion 142. Cutter 110 further includes a frustoconical surface 144 adjacent to back face 140 that is adapted to retain cutter elements 145 that scrape or ream the sidewall 130 of the borehole as the cone cutter rotates about the borehole bottom. Frustoconical surface 144 will be referred to herein as the "heel" surface of cone cutters 110-112, it being understood, however, that the same surface may be sometimes referred to by others in the art as the "gage" surface of a rolling cone cutter.

Extending between heel surface 144 and nose 142 is a generally conical surface 146 adapted for supporting cutter elements that gouge or crush the borehole bottom 134 as the cone cutters 110-112 rotate about the borehole. Frustoconical heel surface 144 and conical surface 146 generally converge in a circumferential edge or shoulder 150 (Figure 7).

As best shown in Figures 5 and 6, cone cutters 110-112 each include a circumferential gage row 160 of inserts 162. Inserts 162 may be rounded or domed shaped or have other shaped cutting surfaces. Cone cutters 110-112 each include a plurality of inner row cutter elements 10, structured as previously described and retained in the cone cutter in a series of spaced, circumferential inner rows 170, 171, 172. In Figure 5, draftsman's license has been employed in order to show the relative spacing of inserts in inner rows 170, 171 and 172, it being understood that a plane through the cone cutter 110 and its axis 124 will not bisect a cutter element in each inner row 170, 171, 172 due to the staggered nature of the inserts from one row to the next, best shown in Figure 6.

Cone cutters 110-112 each include radially outermost row 170 of inner row cutters 10a. In row 170, cutter elements 10a are oriented and retained in the cone such that the blunt front face 34 faces the borehole sidewall 130 when the cutter element is in the position that places it furthest from the bit axis (and closest to the borehole wall). Cone 110 is shown in isolation in Figure 7 wherein the orientation of inserts 10a in inner row 170 is best shown. In this orientation, the plane of symmetry 50 of insert 10a is substantially perpendicular to back face 140 of cone cutter 110.

Referring again to Figures 5 and 6, cone cutters 110-112 also each include a second inner row 171 having a plurality of inserts 10b; however, in inner row 171, the blunt front face 34 is oriented so as to face the direction of rotation of the respective cone cutter. In row 171, the front face 34 of cutter elements 10b are oriented 90

degrees with respect to the orientation of front face 34 of cutter elements 10a in the outermost inner row 170. Cone cutters 110, 111, include a third inner row 172 which, in this embodiment, is formed by conventional conical inserts 173. If desired, row 172 may instead be formed by inserts 10 and, in such case, would preferably have their front face 34 oriented in the direction of cone rotation, as with inserts 10b in inner row 171.

Referring momentarily to Figure 8, a conventional prior art rolling cone bit is shown in cross section in a view in which the cutter elements of all three cone cutters are rotated into a single profile. In this example, the inserts 180 in each of the inner rows of cutter elements are generally conically shaped and, prior to wear occurring, each has spherical apex or cutting tip 181 aligned with its axis element 182. In many formations, these inserts 180 have tended to wear rapidly on the side of the cutting surface facing the borehole wall 130 and, because of such wear, have tended to wear into the shape shown in phantom by the dashed line 183. The detrimental off centre wear such as shown in Figure 8 is typically encountered when a bit is used in a directional drilling assembly employing a downhole mud motor. Once such wear occurred, the cutting surface of the insert 180 became sharper than the original conical shape. This sharper or more brittle insert geometry makes the insert 180 more susceptible to chipping and breakage. Furthermore, upon taking the sharper shape due to this off centre wear, the newly formed peak or apex 184 was effectively moved to a position generally in board of the cutter element axis 182 (toward the centre of the borehole and toward bit axis 11). Because there was less insert material on the in board side

of the cutter element 180 to resist the forces imposed by the borehole side wall 130 onto the newly formed apex 184, this type of off centre wear lead to an increase in insert breakage and lessened the useful life of the bit.

As discussed above with respect to Figures 5-7, in such formations, it is advantageous to employ cutter element 10a in row 170 with front face 34 oriented to face the borehole sidewall 130 so as to better resist the off centre wear. Referring momentarily to Figure 9, bit 100 is shown in a profile view having all inserts 10a on cones 110-112 shown rotated into a single profile. As understood then from reference to Figures 6 and 9, each of the cutter elements 10a in the radially outermost rows 170 on cone cutters 110-112 are oriented to have their front face 34 generally facing the borehole sidewall. The relatively blunt front facing surface 34 is generally wider than the cutting profile of a similarly-sized conventional conical insert (such as insert 180 in Figure 8) such that, by presenting the broadened face 34 towards the borehole sidewall 130, insert 10a is better able to resist the off centre wear experienced by the inserts shown in Figure 8 due, in part, to having a larger surface area opposing the sidewall forces. Furthermore, because the apex 24 of insert 10a is offset from the cutter axis 16 in its unworn condition, and because the offset 26 is in the direction facing the borehole sidewall as insert 10a is employed in inner row 170 (Figures 5,9), then even as wear occurs to front face 34 such that a sharper cutting tip is formed in board from the original position of apex 24, there will still be a substantial portion of the cutter element 10a on the back face 36 behind the cutting tip so as to resist breakage. More specifically, as shown in Figure 9, insert

10a may gradually wear into the shape as shown in phantom by dashed line 31 so as to form a new cutting tip 29. Yet, due to the original offset 26, the newly formed cutting tip 29 remains outboard of insert axis 16, such that a substantial amount of insert material remains behind cutting tip 29 to resist the forces imposed by the sidewall 130, thereby to buttress the cutting tip 29 and thereby to resist and reduce insert breakage. The front face 34 of insert 10a has a generally wider cutting profile then a similarly-sized conventional conical insert and provides greater resistance to off-centre wear because there is greater surface area on face 34 bearing against the borehole sidewall 130. Further, by resisting off-centre wear, inserts 10a also provide increased resistance to bit whirl. Orienting the front face 34 towards the borehole wall 130 lessens the tendency of the borehole forces to cause bit whirl, a phenomenon particularly prevalent when directionally drilling with downhole motors.

Collectively, this orientation of inserts 10a in rows 170 reduces the amount of off centre movement of the bit 100 that is caused by off centre wear to the inner row cutters, slows the rate of wear on the cutters as compared to a standard conical insert and, even after substantial wear to the insert 10a has occurred, offers increased resistance to breakage as compared to conventional conical or chisel inserts. Orienting face 34 towards the borehole wall thus provides resistance to this detrimental wear to the insert and, in turn, extends the life of the bit.

As described above, cutter elements 10b in next inner row 171 are, in this preferred embodiment, oriented differentially from cutter elements 10a in the outermost

inner row 170. As best shown in Figure 6, the transition surface 38 of cutter element 10b generally faces the borehole sidewall while the flattened or blunt front face 34 is oriented in the direction of cone rotation. In this arrangement, the broader front facing surface 34 will first engage the borehole bottom before the narrower more rounded rear face 36 engages the hole bottom. In this way, cutter elements 10b in row 171 achieve much of the benefit of a conventional chisel shaped insert when drilling in soft formations as the front face 34 is wider than a standard conical insert and therefore cuts a wider swath or groove. At the same time, where hard formations are encountered, the forward facing surface 34, with its continuously contoured cutting surface 30 and the absence of sharp stress-creating edges, is less susceptible to breakage than a conventional chisel-shaped insert. Further, because of the offset 26 of the apex 24 from the central axis 16 of the insert 10b, there is more support behind the front face 34 which again provides increased resistance to breakage, particularly after wear has occurred. Orienting the blunt and wider front face 34 of inserts 10b in rows 171 to engage the borehole bottom first maximizes the scraping or gouging action of the cutter elements 10b but still maintains much of the beneficial characteristics of a conical insert when cutting in hard formations.

It is to be understood that in various preferred embodiments of the present invention, cutter elements 10 will be employed only in the outermost of the inner rows on the cone cutters. Thus, notwithstanding the description of the embodiment having cutters 10b in inner row 171 or in other inner rows, the benefits of resisting off-centre wear can be achieved with cutter elements 10 in the outermost

inner row, with conical or chisel shaped inserts or inserts of other conventional shapes in the other inner rows.

Additionally, it is to be understood that although the inserts in the innermost inner row 172 of cones 110-112 have been shown in Figures 5-7 to be conical inserts 173, cutter elements 10 described herein could be employed in row 172 and indeed any other row as the drilling requirements may require. Further, although cutter elements 10 have been shown in two orientations in two separate rows 170, 171, other orientations of cutter elements 10 in rows 170, 171 may be employed. Further still, cutter elements 10 may be interspersed with conventional chisel shaped inserts, conical inserts, or other conventional inserts, rather than employing cutter element 10 at every location within a given inner row.

While cutter element 10 has been shown and described to this juncture as being an insert type cutter element for use in a TCI bit, the cutter element 10 may likewise be employed as a tooth formed in a cone cutter in a steel tooth bit. Thus, the principles and advantages described above for an insert-type bit may likewise be employed and achieved in steel-tooth bits.

Embodiments of the present invention have been described with particular reference to the examples illustrated. However, it will be appreciated that variations and modifications may be made to the examples described within the scope of the present invention.

CLAIMS

1. A cutter element for a drill bit, the cutter element comprising:

a base having a central axis;

a cutting portion extending from said base and having a continuously contoured cutting surface terminating in a generally rounded apex, said cutting surface including:

a first face extending from said base to said apex;

a second face opposite said first face extending from said base to said apex; and,

respective transition surfaces extending between said first and second faces and between said base and said apex;

wherein said cutting portion is symmetrical about a plane containing said central axis and bisecting said first and second faces; and,

wherein said apex is offset a distance from said central axis in the direction of said first face;

said first face being flatter than said second face.

2. A cutter element according to claim 1, wherein said apex is generally spherical.

3. A cutter element according to claim 1 or claim 2, wherein said offset is between 5 and 25 percent of the diameter of said base.

4. A cutter element according to any of claims 1 to 3, wherein said first face has a first cutting profile and said second face has a second cutting profile, said first

cutting profile being wider than said second cutting profile.

5. A cutter element according to any of claims 1 to 3, wherein said first face has a first cutting profile and said second face has a second cutting profile, said second cutting profile falling within said first cutting profile when said profiles are viewed as rotated within a single plane.

6. A cutter element according to any of claims 1 to 5, wherein said continuously contoured cutting surface is convex in every longitudinal profile.

7. A cutter element according to any of claims 1 to 6, wherein said cutting surface is outwardly bowed and includes a bow radius as viewed in every longitudinal profile; and wherein said bow radius changes along said the cutting surface from the intersection of said plane of symmetry and said second face to the intersection of said plane of symmetry and said first face, said bow radius being at its maximum at an angular position closer to said first face than said second face.

8. A cutter element according to claim 7, wherein said cutting surface is outwardly bowed and includes a top radius as viewed in every longitudinal profile; and wherein said top radius changes along said cutting surface from the intersection of said plane of symmetry and said second face to the intersection of said plane of symmetry and said first face, said top radius being at its maximum at an angular position closer to said first face than said second face.

9. A cutter element according to claim 8, wherein said top radius and said bow radius are each at a maximum at the same angular position relative to the intersection of said plane of symmetry and said second face.

10. A cutter element according to claim 7, wherein said bow radius at the angular position where said plane of symmetry insects said first face is greater than said bow radius at the angular position where said plane of symmetry intersects said second face.

11. A cutter element according to claim 10, wherein said top radius at the angular position where said plane of symmetry intersects said first face is greater than said top radius at the angular position where said plane of symmetry intersects said second face.

12. A cutter element for a drill bit, the cutter element comprising:

a base having a central axis;

a cutting surface extending from said base and including a rounded apex offset in a first direction from said central axis, said apex being symmetrical about an apex axis that is substantially parallel to said central axis;

a forward facing cutting surface on one side of said apex axis;

a rear facing cutting surface on the opposite side of said apex axis from said forward facing cutting surface;

wherein said forward facing cutting surface is flatter than said rear facing cutting surface and has a wider cutting profile than said rear facing cutting surface.

13. A cutter element according to claim 12, wherein said apex is offset from said central axis a distance that is greater than 5 percent of the diameter of said base.

14. A cutter element according to claim 12 or claim 13, wherein said cutting surface is defined by a spherical radius at said apex.

15. A cutter element according to any of claims 12 to 14, wherein said offset is toward said forward facing cutting surface.

16. A cutter element according to any of claims 12 to 15, wherein said cutting surface is symmetrical about a plane of symmetry that passes through said central axis and said apex axis and that bisects said forward facing and rear facing cutting surfaces.

17. A cutter element according to any of claims 12 to 16, wherein said forward facing cutting surface and said rear facing cutting surface are each convex in a profile view taken through said apex axis.

18. A cutter element according to claim 17, wherein said cutting surface includes a top portion defined by a top radius and a lower portion defined by a bow radius, wherein said top radius and said bow radius are blended at their intersection so as to form a continuously contoured cutting surface; and,

wherein said bow radius is at a minimum at the angular position where said plane of symmetry intersects said rear facing surface, is at a maximum at an angular position that is more than 90° from the intersection of said plane of

symmetry and said rear facing surface, and has an intermediate value that is between said minimum and said maximum at the angular position where said plane of symmetry intersects said front facing surface.

19. A cutter element according to claim 18, wherein said top radius is at a minimum at the angular position where said plane of symmetry intersects said rear facing surface, is at a maximum at an angular position that is more than 90° from the intersection of said plane of symmetry and said rear facing surface, and has an intermediate value that is between said minimum and said maximum at the angular position where said plane of symmetry intersects said front facing surface.

20. A drill bit for drilling a borehole in earthen formations, the bit having a nominal gage diameter and comprising:

a bit body having a bit axis;

at least one rolling cone cutter rotatably mounted on said bit body and having a plurality of cutter elements disposed in spaced-apart circumferential rows;

a gage row of cutter elements having cutting portions extending to full gage diameter for cutting the corner of a said borehole;

a first inner row of cutter elements disposed radially inboard of said gage row for cutting a said borehole bottom, said first inner row cutter elements having a base retained in said cone cutter, a central axis, and a cutting portion extending from said base;

wherein a plurality of said first inner row cutter elements have a cutting surface comprising:

a generally rounded apex;

a first face extending from said base to said apex; and,

a second face opposite said first face extending from said base to said apex;

wherein said first face is flatter than said second face and wherein said apex is offset a distance from said central axis in the direction of said first face; and

wherein said plurality of first inner row cutter elements are oriented in said cone so that said first face generally faces a said borehole side wall when said cutter element is at its radially outermost position with respect to the bit axis.

21. A bit according to claim 20, wherein all the cutter elements in said first inner row are oriented so as to have their first face generally facing a said borehole side wall when said cutter element is at its radially outermost position with respect to the bit axis.

22. A bit according to claim 20 or claim 21, comprising:

a second inner row of cutter elements disposed radially inboard of said first inner row, said second inner row cutter elements having a base retained in said cone cutter, a central axis, and a cutting portion extending from said base;

wherein a plurality of said second inner row cutter elements have a cutting surface comprising:

a generally rounded apex;

a first face extending from said base to said apex;

a second face opposite said first face extending from said base to said apex; and,

a pair of transition surfaces extending between said first and second faces and between said base and said apex;

wherein said first face is flatter than said second face and wherein said apex is offset a distance from said central axis in the direction of said first face; and,

wherein said plurality of second inner row cutter elements are oriented in said cone so that one of said transition surfaces generally faces a said borehole side wall when said cutter element is at its radially outermost position with respect to the bit axis.

23. A bit according to claim 22, wherein all the cutter elements in said second inner row are oriented in said cone so that one of said transition surfaces generally faces a said borehole side wall when said second inner row cutter element is at its radially outermost position with respect to the bit axis.

24. A bit according to claim 22 or claim 23, wherein for each of said first and second plurality of cutter elements, the first face has a cutting profile width that is greater than the cutting profile width of the second face.

25. A drill bit for drilling a borehole in earthen formations, the bit having a predetermined gage diameter and comprising:

a body with a bit axis;

at least one rolling cone cutter rotatably mounted on said bit body and adapted to rotate in a predetermined cutting direction;

a gage row of cutter elements on said cone cutter having cutting portions extending to full gage diameter for cutting the corner of a said borehole;

a first inner row of cutter elements radially in board of said gage row, said first inner row cutter elements having a central axis and a cutting portion extending from the cone cutter, said cutting portion including a generally rounded apex, a first face extending from the cone cutter to said apex, and a second face opposite said first face and extending from said cone cutter to said apex, said first face being flatter than said second face and said apex being offset a predetermined distance from said central axis in a direction of said first face, said first inner row cutter elements being oriented in said cones such that said first face generally faces a said borehole sidewall when said cutter element is at its radially-outermost position with respect to the bit axis.

26. A bit according to claim 25, comprising a second inner row of cutter elements radially in board of said first inner row of cutter elements, said second inner row cutter elements having a central axis and a cutting portion extending from the said cone cutter, said cutting portion including a generally rounded apex, a first face extending from said cone cutter to said apex, and a second face opposite said first face extending from said cone cutter to said apex, wherein the first faces of said second inner row cutter elements are flatter than the respective second faces of said second inner row cutter elements and wherein said apices of said second inner row cutter elements are offset a distance from said central axis in a direction of the respective first faces.

27. A bit according to claim 25 or claim 26, wherein said second inner row cutter elements are oriented such that said first faces of said second inner row cutter elements generally face in said predetermined cutting direction.

28. A bit according to any of claims 25 to 27, wherein said first faces of said second inner row cutter elements are wider than the respective second faces of said second inner row cutter elements.

29. A bit according to any of claims 25 to 28, comprising a third inner row of cutter elements radially in board of said second inner row of cutter elements, said third inner row cutter elements having a central axis and a cutting portion extending from said cone cutter, said cutting portion including a generally rounded apex, a first face extending from said cone cutter to said apex, and a second face opposite said first face extending from said cone cutter to said apex, wherein said first faces of said third inner row cutter elements are flatter than the respective second faces of said third inner row cutter elements, and wherein said apices of said third inner row cutter elements are offset a distance from said central axis in a direction of the respective first faces; and wherein said third inner row cutter elements are oriented such that said first faces of said third inner row cutter elements generally face in said predetermined cutting direction.

30. A drill bit for drilling a borehole in earthen formations, said bit having a nominal gage diameter and comprising:

a bit body having a bit axis;

at least one rolling cone cutter rotatably mounted on said bit body and having a plurality of cutter elements disposed in spaced-apart circumferential rows;

a gage row of cutter elements having cutting portions extending to full gage diameter for cutting the corner of a borehole;

a plurality of first inner row of cutter elements disposed radially inboard of said gage row for cutting a said borehole bottom, said plurality of first inner row cutter elements having a base retained in said cone cutter, a central axis, and a cutting portion having a cutting surface extending from said base and terminating in a generally rounded apex, said cutting surface including:

a first face extending from said base to said apex; and,

a second face opposite said first face extending from said base to said apex;

wherein said cutting portion is symmetrical about a plane containing said central axis and bisecting said first and second faces; and,

wherein said apex is offset a distance from said central axis in the direction of said first face, said first face being flatter than said second face; and,

wherein said plurality of first inner row cutter elements are oriented in said cone so that said first face generally faces a said borehole side wall when said cutter element is at its radially outermost position with respect to the bit axis.

31. A bit according to claim 30, wherein said cutting surfaces of said plurality of first inner row cutter elements are outwardly bowed and include a bow radius as viewed in every longitudinal profile; and wherein said bow

radius changes along said the cutting surface from the intersection of said plane of symmetry and said second face to the intersection of said plane of symmetry and said first face, said bow radius being at its maximum at an angular position closer to said first face than said second face.

32. A bit according to claim 31, wherein said cutting surface of said plurality of first inner row cutter elements is outwardly bowed and includes a top radius as viewed in every longitudinal profile; and wherein said top radius changes along said cutting surface from the intersection of said plane of symmetry and said second face to the intersection of said plane of symmetry and said first face, said top radius being at its maximum at an angular position closer to said first face than said second face.

33. A bit according to any of claims 30 to 32, wherein all the cutter elements in said first inner row are oriented so as to have their first face generally facing a said borehole side wall when said cutter element is at its radially outermost position with respect to the bit axis.

34. A cutter element substantially in accordance with any of the examples as hereinbefore described with reference to and as illustrated by Figures 1 to 7 and 9 of the accompanying drawings.

35. A drill bit substantially in accordance with any of the examples as hereinbefore described with reference to and as illustrated by Figures 1 to 7 and 9 of the accompanying drawings.

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Application No: GB 0325863.9 **Examiner:** Gareth Bond
Claims searched: 1 & 30 **Date of search:** 29 March 2004

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X	1,2,4,6, 30,33	US5881828	(Smith International Inc) See figures and columns 2 to 7.
X	1,2	US5415244	(Smith International Inc) See figures 1 to 4 and column 2 line 58 to column 3 line 27.
X	1	US5322138	(Smith International Inc) See figures 16 to 19 and column 5 lines 47 to 68.
X	1	US4108260	(Hughes Tool Company) See figures 2 to 4 and column 2 lines 16 to 50.

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X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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WPI, EPODOC, PAJ